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FMIT ALIGNMENT CART*

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Summary

The Fusion Materials Irradiation Test (FMIT) Facility alignment cart must perform several functions. It must serve as a fixture to receive the drift-tube girder assembly when it is removed from the linac tank. It must transport the girder assembly from the linac vault to the area where alignment or disassembly is to take place. It must serve as a disassembly fixture to hold the girder while individual drift tubes are removed for repair. It must align the drift tube bores in a straight line parallel to the girder, using an optical system. These functions must be performed without violating any clearances found within the building. The bore tubes of the drift tubes will be irradiated, and shielding will be included in the system for easier maintenance.

Receiving of Girder

The girder is removed from the tank as a unit that contains several drift tubes. The girder itself holds the drift tubes and contains their adjusting mechanism. The drift-tube stems pass through the spanner hatch below the girder; the spanner hatch forms a vacuum seal with the top of the tank. There are bellows that form a seal between the drift-tube stems and the spanner hatch.

When the girder is lifted out of the tank, the spanner hatch hangs below it on a set of rigid rods. The girder is lifted by an overhead crane and is carried down the length of the tank to the High-Energy Beam Transport (HEBT) area. Here the girder is lowered into the alignment cart, which receives it by supporting it at points corresponding to those on the tank; thus allowing the girder, drift tubes, and spanner hatch to be supported in the same manner as when on the tank.

Transport

After the girder is placed in the alignment cart, the cart is moved on air pads through a door leading out of the HEBT area and into the final alignment and diagnostic check area. It also is possible to move the cart under the hoistway in order to remove the cart or the girder assembly from the building.

Methods to Find the Magnetic Center of Drift-Tube Quadrupoles

The centerlines of the drift-tube bores will be aligned according to the actual magnetic centers of the magnetic quadrupoles contained within them. There are two methods that will be used to find the magnetic centers, both of which have been used to find magnetic centers of magnets in other applications.

The taut-wire method consists of a wire stretched through the center of the bore. The wire is supported on either end by movable supports, and the sag of the wire at the point where it passes through the bore can be calculated. A current pulse is passed through the wire, and if the wire's path does not lie through the magnetic center of the quadrupole, the wire jerks to the side. Motion detectors indicate this jerk, and the wire position is adjusted until the wire remains still, indicating it is passing through the magnetic center. Probably this method will be used to find the magnetic center before a drift tube is inserted in the girder. The relative position of the magnetic center to the bore centerline will be noted, and a plug target with adjustable cross-hairs will be inserted in the bore for the actual alignment.

The Bitter-figure method uses a vial containing a mixture of ferrous-ferric oxide (a colloidal iron oxide) in a viscous medium. When polarized light is passed through the vial in a quadrupole field, and then viewed through a cross-polarized filter on the other side of the vial, a cross-hair-like pattern is seen, representing the magnetic-cell boundaries; and the intersection of the crossing lines represents the quadrupole's magnetic center. Experiments on this method have yielded accuracies of better than 0.08 mm (0.003 in.), when carefully used. It will be used to directly sight in on the magnetic centers while the drift tubes are being aligned. A container, which contains a lighting source, polarizing filter, and fluid vial, will be inserted into the drift-tube bores. The vial will be observed through an alignment scope, and will be used to bring the magnetic centers into conformance. We have found that the second polarizing filter works best when placed over the eyepiece of the alignment scope.

Alignment Method

Figure 1 shows the alignment cart rolled into the alignment dock. Before the girder is put into the tank after initial assembly, after repair, or after removal to check alignment, the drift tubes will be realigned. This is to insure that the magnetic centers of each drift tube lie on a straight line. Because the group of drift tubes on each girder must line up with the group on the next girder while the drift tube bores are inaccessible inside the tank, an external set of cross-hair sights on the side of the girder is provided for alignment between adjacent girders.

The external cross-hairs represent a line parallel to the line through the drift tubes. The girders are mounted on kinematic mounts and girder orientation can be adjusted relative to the tank to bring the external cross-hairs of a girder into alignment with the girder adjacent to it.

It is important that the external sights not only be parallel to the bore-sight line, but also that the vertical and horizontal distance offset between the bore and external sight be the same for every girder. Also, it is necessary to assure that the roll angle about the girder's long axis remains the same in the tank as in the alignment cart so that these horizontal and vertical distance axes are not rotated. This rotation is controlled by mounting a leveling device on the girder in the roll-axis direction. A similar device also levels in the girder-pitch axis.

The vertical and horizontal distances are set by targets that are mounted on a fixed frame or wall.

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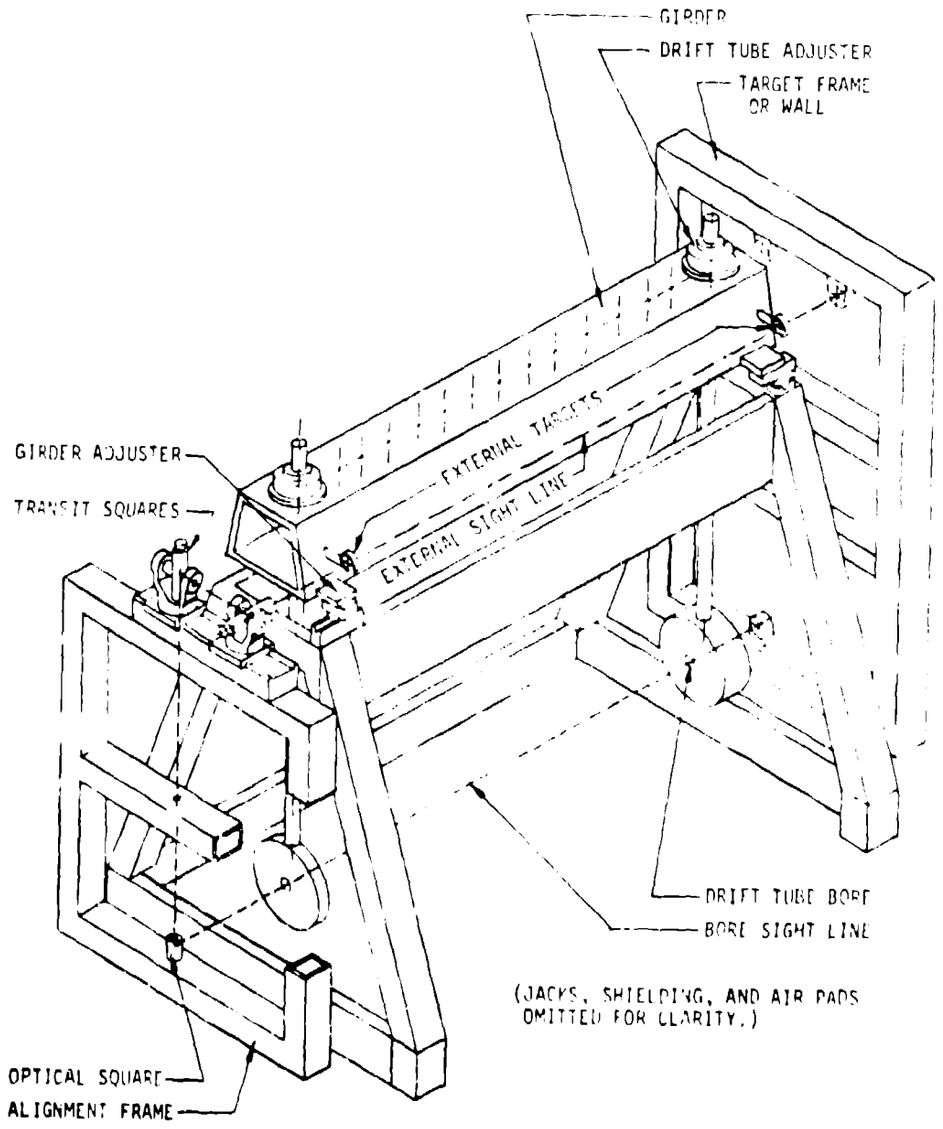

Fig. 1. Alignment cart and dock.

These targets form the terminations of the external and bore sight lines. Because some radiation may escape from the ends of the bores, the bore sight line is not viewed directly. Instead, the bore is viewed through an optical square (accurate right-angle prism) at the end of the bore by looking through a transit square (optical scope capable of establishing sight lines at an accurate right angle to each other) mounted above the optical square. The optical square, bore sight line transit square, and a transit square for sighting the external sight line are arranged so that all angles are square within the accuracy of the equipment; and the two sight lines are parallel horizontally (for control of cosine-related errors), and have a separation in the vertical and horizontal directions fixed by the permanently mounted targets.

The alignment dock would be used by first manipulating the transit squares and optical square, so that the sight lines of the two transit squares are parallel and separated by a distance defined by the permanently mounted targets. The alignment cart is then rolled into the dock and is positioned to an approximate location. The girder is leveled in the roll and pitch planes by kinematic mounts on the cart, the location of which corresponds to those on the tank, and the external sights on the girder are adjusted to conform with the external sight line. The drift tubes then are adjusted individually by the use of Bitter-figure vials, or by adjustable cross-hair bore inserts, calibrated by the taut-wire method. When the drift tubes' magnetic centers lie in a straight line on the bore sight line, alignment is complete. The girder then can be reinstalled in the tank, and its external sights made to line up with the external sights on an adjacent girder by adjusting the kinematic mounts supporting the girder on the tank.

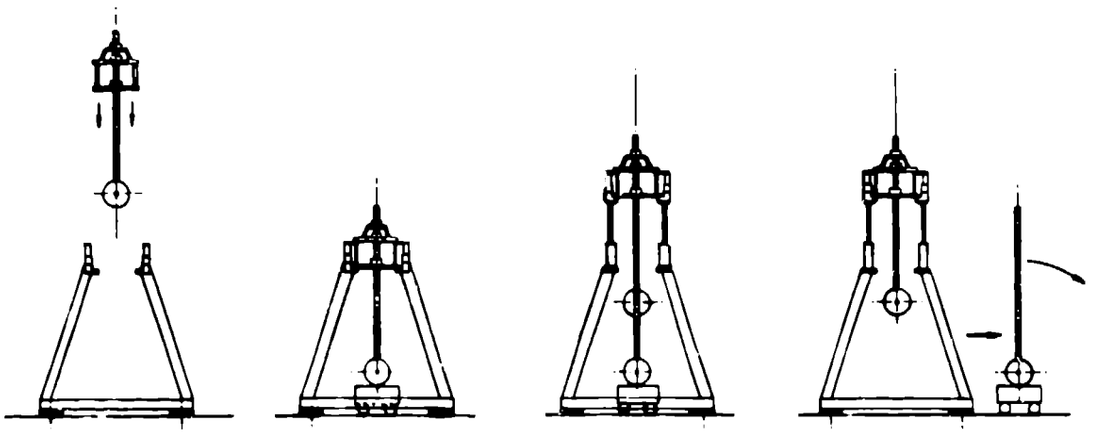

Fig. 2. Drift tube removal.

Removal of a Drift Tube

To remove a drift tube from the girder, the girder is first removed from the tank and put on the alignment cart; then the alignment cart is moved into the final alignment area. A special dolly is placed under the drift tube, and the attachments to the drift tube that fasten it to the girder are removed, freeing the drift tube from the girder.

Figure 2 shows the disassembly procedure. Because of the low ceiling clearances in the alignment area, it is not possible to use a crane to raise the girder. The girder and the remaining drift tubes are raised off the cart by jacks on each corner. The drift tube being removed remains on the special dolly as the girder slides up and off the drift-tube stem, and then it is moved sideways underneath the girder and out of the cart frame. After the drift tube is removed, it is put into a container, and its stem is gently laid horizontally on supports within the container.

The girder is raised by four ball-screw threads, one on each corner of the cart. The screw threads are nonrotating and serve as jack legs to raise the girder. The ball nuts rotate around them, and are connected by drive shafts and 90° drives to a drive motor with a reduction gear and holding brake. This jacking system is contained on the cart, with the drive motor located on the cart's side; thus it is possible to raise the girder at any location in the building.

Shielding

Shielding will be provided around the drift-tube shell and bore-tube area to provide personnel protection. Approximately 2.5-cm-thick (1 in.) lead will be used as a shielding material, and will be in the form of "clamshells", positioned on either side of the drift-tube shells. The bore will be shielded on either end, except for holes for the bore sight line.

Conclusion

The FMIT alignment cart provides an integrated system for transportation and alignment of the drift-tube girder. It can be combined with the alignment dock to establish external sight lines to align each girder with an adjacent girder in the tank, so that the magnetic centers of all drift tubes lie in a straight line.